

# Developmental Mathematics: Challenges, Promising Practices, and Recent Initiatives

By Barbara S. Bonham and Hunter R. Boylan

**ABSTRACT:** Developmental education has increasingly become part of the national debate in higher education. This is particularly true for developmental mathematics courses which, in general, have the highest rates of failure and noncompletion of any developmental subject area. This manuscript describes the current state of the art in developmental mathematics, discusses major initiatives designed to reform and improve success rates, and identifies research-based teaching practices associated with improved student performance in developmental mathematics courses.

*Developmental mathematics as a barrier to educational opportunity represents a serious concern.*

There is considerable public debate about the underpreparedness of students entering colleges today and the efficacy of responses to this underpreparedness. There are a large number of students who place into developmental courses, particularly mathematics, and are prevented from achieving their educational goals because they never complete these courses. Developmental mathematics as a barrier to educational opportunity represents a serious concern for the students as well as higher education policy makers.

Sierpinska, Bobos, and Knipping (2008) discuss the sources of numerous frustrations expressed by students in a university-level prerequisite mathematics course. Examples include the irrelevance of course material, disinterest by faculty teaching courses, a lack of support from the college, and a lack of understanding from their instructors.

Developmental mathematics programs, including courses and related support services, ostensibly exist on college campuses to help students achieve their goals. Yet, in many cases, they have become road blocks to students' success. Courses which were originally designed to promote student academic achievement now often serve as barriers to that achievement. In a summary of data from the U.S. Department of Education, Noel-Levitz (2006) reports,

In all of higher education, including four-year institutions, there is no harder course to pass than one in developmental mathematics. Basic Algebra, in fact, receives top billing in a report from the U.S. Department of Education on the highest failure and withdrawal rates for postsecondary courses. (p.2)

Drawing on the research of Bailey, Jenkins, and Leinbach (2005), Epper and Baker (2009) state, "The challenge of raising math skills is further compounded by the fact that students who test into remedial math coursework are disproportionately minority and disproportionately first-generation, two characteristics of at-risk students" (p. 3).

According to the most recent National Center for Education Statistics (NCES) study in this area entitled *Remedial Education at Degree Granting Postsecondary Institutions* (Parsad & Lewis, 2003), approximately three-fourths of the colleges and universities in the U.S. that enrolled freshmen offered at least one developmental course. Of those that offered developmental mathematics, 60% offered between 2 and 4 courses, with an average of 2.5 courses. The average for public two-year colleges was 3.4 courses. This means that a student placing in the lowest level of developmental mathematics at a community college must take approximately 10 hours of mathematics courses before even having an opportunity to attempt college-level mathematics. The same NCES study reports that mathematics was the developmental course most likely offered by colleges and universities, with 72% reporting offering at least one developmental mathematics course (68% offered developmental writing courses and 56% offered developmental reading courses). Seventy-two percent of the developmental mathematics courses are offered in the traditional academic department rather than in a developmental education department. These courses usually (73-78%) receive only institutional, not degree credit. The courses may, therefore, be used to qualify for financial aid but do not usually count toward graduation.

In a special report on community colleges, the NCES (Provasnik & Planty, 2008) reported that, for the 2006-2007 term, there were 1,045 community colleges in the United States enrolling 6.2 million students or 35% of all students enrolled in postsecondary institutions. Nearly 75% of students entering two-year colleges must take one or more developmental mathematics courses (Noel-Levitz, 2006). In Fall 2000, the proportion of entering freshmen who were enrolled in remedial courses was larger for mathematics (22%) than for writing (14%) or for reading (11%) (Parsad & Lewis, 2003). According to Lutzer, Rodi, Kirkman, and

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Maxwell (2007), the results from the 2005 survey by the Conference Board of Mathematical Sciences revealed enrollment in precollege mathematics courses accounted for 56% of total mathematics and statistics enrollment in two-year institutions.

For many students entering college these courses have become a frightening obstacle. For some students, it prolongs their time at colleges, requires them to take and retake these courses, and results in eventual failure or withdrawal. Furthermore, a significant number of college students never enroll in the developmental mathematics courses into which they place. Based on data from the Achieving the Dream sample, Bailey (2009) reported that about one-fifth of all students in that sample who needed to take developmental mathematics courses did not enroll in a single one of these courses over a 3-year period.

## Completion of the Developmental Math Sequence

Unfortunately not many of those who do enroll complete the full sequence of recommended developmental mathematics courses. In a statewide study including a sampling of two-year and four-year colleges, the completion rate for the full sequence of developmental courses was the lowest in mathematics at 21% (Schiel & Sawyer, 2002). In a much larger and more controlled national study drawing on college transcript data from the National Educational Longitudinal Study (NELS) Attewell, Lavin, Domina, and Levey (2006) report that only 30% of students pass all of the developmental mathematics courses in which they enroll. The NELS is based on a 1988 representative cohort of 8th graders who went on to college and for whom data was tracked up to 2006 in this study. The math sequence completion difference between these studies may be influenced by two important factors: (a) the exclusion of any students who return to college many years after leaving high school from the longitudinal database and (b) the use of a national representative sample compared with a smaller, statewide, nonrandom sample.

Although developmental mathematics courses have proven to be an obstacle for many students, research reflects that students who passed their developmental mathematics course requirements were as successful in subsequent mathematic courses as those who were not required to take developmental mathematics courses (Bahr, 2008). Similar findings were reported in a statewide study conducted by ACT involving students from both two-year and four-year colleges (Schiel & Sawyer, 2002). Results from this study indicated that developmental mathematics courses were effective for those who completed them. Unfortunately only 21% of the students in this study completed their developmental mathematics coursework.

Fortunately, all of the attention focused on developmental mathematics programs at two- and four-year colleges has resulted in a major shift in the content, organization, and delivery of some of these programs. Stuart (2009) reports that colleges are changing from simply providing access to students who are underprepared for college-level courses to a more rigorous involvement, including study of and development of courses and services to meet the very diverse demographic backgrounds of students. He notes, "more and more colleges and universities are ditching the old stigma associated with remedial education and reinventing their remedial and retention programs" (Stuart, 2009, p. 14). In the last decade, there has been an increase in the application and use of research-based best instructional practices in developmental mathematics programs and in the use of innovative approaches to teaching and learning. Early results are revealing significant improvements in students' success. These are discussed in the following

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sections which outline successful teaching practices used in developmental mathematics, appropriate delivery models, efforts to address affective factors, expanded professional development, new partnerships, and promising innovative initiatives.

## Teaching Strategies

Successful programs utilize multiple teaching and learning strategies (Boylan, 2002; Epper & Baker, 2009; Massachusetts Community Colleges Executive Office, 2006) to improve students' success in developmental mathematics. A report published by the OVAE (Office of Vocational and Adult Education; Golfin, Jordan, Hull, & Ruffin, 2005) focused on developmental mathematics instruction and provided recommendations for promising practices emerging from their literature review. These included greater use of technology as a supplement to classroom instruction, integration of classroom and lab instruction, offering students a variety of delivery formats, project-based instruction, proper student assessment and placement, integration of counseling for students, and professional development for faculty.

Other reports and studies have identified the successful application and use of varied teaching techniques as strategies to improve students'

success and retention in developmental mathematics. Examples of these include: mastery learning (Boggs, Shore, & Shore, 2004; Rotman, 1982); attention to affective factors (Hamerman & Goldberg, 2003; Taylor & Galligan, 2006); mentoring programs (Sperling & Massachusetts Community College, 2009; Visher, Butcher, & Cerna, 2010); integration of math study skills and learning strategies (Acee, 2009; Nolting, 1997); supplemental instruction (Blanc, DeBuhr, & Martin, 1983; Martin & Arendale, 1994; Peacock, 2008; Phelps & Evans, 2006); active learning, including cooperative and collaborative learning approaches (Barkley, Cross, & Major, 2005; Davidson & Kroll, 1991); contextual learning (Crawford, 2001), problem solving, and modeling (AMATYC, 2006; Ashwin, 2003); integrated classroom activities, laboratory activities, and learning centers (Boylan, 2002; Perin, 2004).

## Delivery Models

In an overview of current practices Epper and Baker (2009) identified a number of special projects being implemented in community colleges over the last 5 years. For example, Foothills College in California has implemented a program titled Math My Way. This program focused on intensity of instruction (additional time on task and an emphasis on mastery) while utilizing self-paced delivery and technology (ALEKS software), Supplemental Instruction, tutoring, and classes held on consecutive days. Results reveal a 20% higher success rate in college-level math for program completers. Other projects described in the report by Epper and Baker are course redesign projects supported by The National Center for Academic Transformation (NCAT). Jarmon (2009a) commented in a presentation that "Course redesign is a process of redesigning whole courses (rather than individual classes or sections) to achieve better learning outcomes at a lower cost by taking advantage of capabilities of information technology." Course redesign can involve a whole course, as is the case at Cleveland State Technical College in Tennessee, or focus on competencies needed for specific programs or courses, such as the program at Jackson State College in Tennessee. The former is referred to as the "emporium model" and the latter as the "linked workshop model" (Jarmon, 2009b).

There are a variety of redesign models that have recently emerged. These include supplemental, replacement, emporium, fully online, buffet, and linked workshops (Jarmon, 2009b). Different approaches have been taken in the redesign of the curriculum in developmental mathematics. According to Lucas and McCormick (2007), some have accelerated it, some slowed it down, and some attempted to decrease the number of topics.

Examples of courses recommended as targets for redesign are those with high withdrawal/failure rates, those drawing from students with

inconsistent preparation, those having difficulty getting qualified adjuncts, or those from which students have difficulty in subsequent classes. Course redesign is not specifically targeted to developmental mathematics alone. For instance, the redesign project using the Math Emporium model at Virginia Tech and the University of Alabama are for higher levels of mathematics. Course redesign promotes the use of multiple teaching approaches rather than a single method. Many of these approaches are supported by research or have been identified as promising practices in developmental mathematics. These research-based or promising practices include mastery learning, active learning, individualized assistance, modularization, or personalized assistance (such as Structured Learning Assistance, frequent feedback, or the use of laboratories rather than classrooms). In these approaches technology is utilized where it is most appropriate, on homework, quizzes, and exams, for example. Tutorials are delivered through computer-based instruction supplemented by small-group instruction and test reviews. This approach fosters greater student engagement with the material as well as with each other.

One of the major advantages of the project is that it encourages the use of multiple approaches to teaching developmental mathematics. Students actually learn math by doing math rather than spending time listening to someone talk about doing math. The major disadvantage can be an overreliance on the technology to deliver all instruction with little or no intervention, even when students are experiencing difficulty. In a discussion of lessons learned regarding course redesign one caution noted was, “don’t necessarily redesign around technology....always consider students’ needs and skills when choosing the online tools” (Foreign Language Resource Center, 2009, p. 1). Additional recommendations regarding course redesign from colleges involved in the process include the following: (a) establish clear goals, learning outcomes, and assessment methods; (b) insure that the project is faculty driven with strong administrative support; (c) choose carefully what can be done most effectively online; (d) develop a conceptual framework to guide the process; (e) build institution-wide support; and (f) deliver a good orientation for students (Foreign Language Resource Center, 2009; Search, 2009). The Tennessee Board of Regents has committed to a redesign initiative in developmental mathematics and English. This initiative involves 9 universities and 13 community colleges (NCAT, 2009).

### Affective Factors

The affective domain is frequently an untapped area in attempts to promote students’ achievement and retention in developmental mathematics programs. Yet research dating back to the early 1980s

has revealed the importance of its relationship to students’ success in mathematics (Schoenfeld, 1983). In the last decade increased attention has been given to this relationship, particularly by researchers in the area of educational psychology as well as educators in the field of mathematics education (Muis, 2004). The importance of the relationship between the cognitive and affective factors influencing students’ success in developmental mathematics cannot be ignored. Bandura’s (1997) work in the area of social cognitive theory maintains that it is the students’ beliefs about the value of the learning experience, their expectations of success, and their enjoyment of it that will motivate them to engage material actively and persist in spite of initial failures.

Research supports the relationship between attitude toward mathematics and achievement in mathematics (De Corte, Verschaffel, & Depaepe, 2008; Ma & Xu, 2004; Muis, 2004). Ma and Xu (2004) found a reciprocal relationship between every attitudinal measure used in this study and

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mathematics achievement. This is a significant study contributing valuable information regarding the relationship between students’ attitudes and achievement.

In addition to the relationship between attitude toward mathematics and students’ success, research findings also reveal the impact of other affective factors including low self-efficacy and confidence in ability to do mathematics, test anxiety, and math anxiety (Bates, 2007; Bonham, 2008; Hall & Ponton, 2005; Higbee & Thomas, 1999; Rodriguez, 2002; Tobias, 1993). These affective variables can become barriers to students’ success and have a “negative and inhibitory impact on learning and performance in mathematics” (De Corte, Verschaffel, & Depaepe, 2008, p. 25).

This is a rich area of information for educators designing developmental mathematics courses and one that should definitely not be ignored by anyone attempting to improve student performance in developmental mathematics. Students, faculty, and support staff need to understand the influence of affective factors on students’ success and retention in developmental mathematics. They should be familiar with and employ strategies to help alleviate mathematics anxiety, build self-confidence, and maximize student learning in mathematics.

Another important point is that collaborative efforts among students result in a higher degree of accomplishment by all participants; students

help each other and in doing so build a supportive community. This raises their performance level as well as their belief in their ability to do well in mathematics (Barkley, Cross, & Major, 2005; Davidson & Kroll, 1991). Galbraith and Jones (2006) discuss the use of team learning in which students act as teaching assistants. The use of learning groups also contributes to the development of trust and cooperation among the students as well as with the instructor. DePree (1998) has found that small-group instruction significantly increases math confidence for historically underrepresented groups such as female, Hispanic-American, and Native-American students.

Writing—such as journal, error analysis, and student-developed word problems—can also enhance learning in mathematics; it can improve students’ understanding of mathematics as well as their attitudes and beliefs about mathematics. Research reveals that it is an effective strategy for minority students and for students with learning disabilities (Loud, 1999; Pugalee, 1997). However, as Meier and Rishel (1998) point out, these student writing assignments must be carefully designed in order to successfully foster student learning and engagement. Without a connection to the class material, a writing assignment will be less engaging to students and unlikely to increase student understanding or attitude towards mathematics.

An effective way to reduce math anxiety is to create a safe learning environment in which students feel comfortable expressing themselves without fear or ridicule. Use of the following strategies can foster a safe environment and create a sense of belongingness: discuss classroom etiquette, use icebreakers or group warm-up activities, teach relaxation techniques, and use affective assessment instruments to help students understand their attitudes toward learning (Bonham, 2008; Levine-Brown, Bonham, Saxon, & Boylan, 2008; Saxon, Levine-Brown, & Boylan, 2008).

Based on the findings of Peskoff (2000) and Nolting (2002), a list of strategies for coping with and helping to alleviate mathematics anxiety are listed in *Beyond Crossroads* (AMATYC, 2006). Information for actions to be taken by faculty and departments are also delineated. These include recommendations for workshops on study skills, math anxiety, and multiple assessment use.

### Professional Development

“As mathematics teaching changes across the world, faculty teaching developmental mathematics courses must rethink both what should be taught and how it should be taught” (Mathematical Association of America, 2010, p. 1). The implications of that statement affect recruitment and hiring, professional development, and curriculum review and revision in the area of developmental

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mathematics. Many educators teaching developmental mathematics are highly qualified in the discipline of mathematics. However, they may have limited coursework or formal training in developmental education, college teaching, student learning, or the application of varied teaching strategies. Those who have been teaching developmental mathematics can attest to the fact that it differs substantially from teaching more advanced college-level math courses. New faculty may question why these students are in college or why these courses are being taught at the college level. According to the AMATYC standard on professionalism (2006), developmental mathematics educators need specialized preparation in the following areas: developmental mathematics, technical mathematics, teaching preparation, intensive math background, and statistics knowledge. These guidelines are recommended for use in recruitment, hiring, orientation, and mentoring diverse mathematics faculty.

According to Boylan (2002), training and professional development is a priority in the most successful developmental programs. Faculty and staff working with developmental students are supported and encouraged to attend conferences, training institutes, and graduate courses. Those who participate in such activities are encouraged to share what they have learned with their colleagues in formal and informal settings. It is important to realize that a sustained and intensive series of professional development activities are much more effective than "one shot" professional development workshops (Boylan, 2002).

## Partnerships

Improving the percentage of students who are prepared for college-level mathematics involves a complex set of issues related to learning, assessment, curriculum, teaching, and professionalism. Mathematics educators at all levels (PK-16 including Adult Basic Skills) need to build public understanding and support for the changes in mathematics education. Building partnerships with Adult Basic Education programs, ESOL, high schools, other colleges, business and industry, as well as with the local community agencies is recommended by the major associations in the field of mathematics as well as by many national projects (ACHIEVE, 2004; Adelman, 2006; AMATYC, 2006; Boylan, 2002). These collaborative efforts can promote the alignment of exit and entrance requirements. Such efforts can also create partnerships with faculty in other disciplines to integrate mathematics across the curriculum and with business and industry to ensure that necessary employee skills and strategies are included in mathematics courses and programs.

## Special Projects Focused on Developmental Mathematics

There have been a number of recent improvement projects sponsored by major associations in mathematics and national organizations. These have provided information to guide the design and development of effective learning environments for developmental mathematics.

The American Mathematical Association of Two-Year Colleges has been very focused recently on developmental mathematics projects. In past years their two publications, *Crossroads in Mathematics* and *Beyond Crossroads in Mathematics*, have contributed significantly to establishing mathematics standards and guidelines for the first 2 years of college. The first document, *Crossroads in Mathematics*, published in 1995,

emphasized desired modes of student thinking and guidelines for selecting content and instructional strategies. The purposes of the second standards document, *Beyond*

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*Crossroads*, was to renew and extend the goals, principles, and standards set forth in *Crossroads* and to continue the call for implementation...with an additional set of standards which focus on student learning and the learning environment, assessment of student learning, curriculum and program development, instruction, and professionalism. (AMATYC, 2006, p.1)

Recent activities supported by AMATYC include The Syllabus Project, which provides online posting and sharing of course syllabi for different levels of developmental math courses. Also available are links to organizations and resources.

Some of the most current activities include the AMATYC's partnership with Monterrey Institute for Technology and Education (MITE). MITE, with a 5 million dollar grant from Bill and Melinda Gates, will combine the four courses required in most remedial math sequences. Using preassessments and multiple learning approaches, MITE hopes to create coursework that can be customized to each individual student's needs.

The Carnegie Foundation for the Advancement of Teaching has undertaken a project to make "mathematics a gateway not a gatekeeper course" (Bryk & Triesman, 2010). The authors note that redesigning the curriculum content is necessary

but not sufficient to stem the crises of failure and noncompletion in developmental mathematics. They also argue that there needs to be an integrated academic support system as well. "We need to strengthen the connections of students to successful peers, to their institutions, and to pathways to occupations and education" (Bryk & Triesman, 2010, p. 20). Carnegie's development of a statistics pathway de-emphasizes algebra and focuses on real-life, workforce oriented, mathematics tasks. This model may help solve the problems for a large number of community college students needing developmental mathematics courses. This pathway is designed to fulfill math requirements for many occupations and to help students become more academically successful. The project team has already met with community college leaders and members of mathematics and national education groups. They are working in collaboration with Achieving the Dream and the California Community College System's Basic Skills Initiative (Boroch et al., 2007). The groundwork for this project began in the Summer of 2010 when community college teams met with designers, researchers, and practitioners to begin the design and development of resources and assessments for the pathway.

## Conclusion

It is unfortunate that developmental courses, once envisioned as a gateway to educational opportunity, have become barriers to that opportunity for many students. Although those who pass developmental courses tend to do well in college, an unacceptable number fail to complete these courses. This is most true in developmental mathematics.

Fortunately, there is a great deal of research to identify promising practices that may improve the quality of developmental mathematics instruction. There are also a number of projects being undertaken to redesign the content and improve the delivery of developmental mathematics courses. For these efforts to be successful it will be necessary for professional associations, foundations, policy makers, and developmental mathematics instructors to collaborate in changing the way developmental mathematics courses are structured, taught, and delivered. This will be neither an easy nor a short-term process. However, it is a process that must be undertaken if educational opportunity is to remain a reality in U.S. postsecondary education. We can no longer deny our weakest and poorest citizens the opportunity to obtain a college credential simply because we are unable to teach them how to factor polynomials.

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## MICHIGAN DEVELOPMENTAL EDUCATION CONSORTIUM

Introduces...

### 29<sup>th</sup> Annual MDEC Conference

April 3<sup>rd</sup> & 4<sup>th</sup>, 2014

Details will be available on the website Fall of 2013.

## CONFERENCE UPDATE

*The 28<sup>th</sup> Annual MDEC Conference was held on March 21<sup>st</sup> and 22<sup>nd</sup>, 2013. MDEC would like to thank all of the presenters for their fine work.*

*If you have ideas for a conference theme, keynote speakers, or workshop presenters for next year's conference, please contact a board member prior to our mid-June planning retreat.*

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